

VALINIA INIA, A NEW EARLY STORAGE ONION VARIETY FOR CENTRAL SOUTH CHILE

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In Central South Chile, storage onion varieties (*Allium cepa* L.) sold domestically usually begin the maturation process in March, which implies that a large proportion of bulbs do not mature adequately and do not resist prolonged storage. This situation led the Quilmapu vegetable program of the Instituto de Investigaciones Agropecuarias INIA to select an early maturing onion variety. This breeding method involved a recurrent selection with free plant crossing that began in 1994 on a population of 2000 plants of the 'Valenciana' commercial variety. Plants were first selected when they reached physiological maturity (tops down before 28 February), and then for shape, size, storage capacity, and single-centered bulbs. The result of the program was 'Valinia INIA', a type of Valenciana onion variety: early maturing, medium-sized bulb, spherical, yellow, and resistant to sprouting during storage. From the 2001-2002 to the 2008-2009 season, variety assays were carried out to compare 'Valinia INIA' with commercial cultivars, i.e., 'Sintética 14', 'Grano de Oro', and 'Valenciana Cobra'. 'Valinia INIA' precocity exceeded the other varieties in all seasons with a mean of 1.5 wk ahead of 'Sintética 14', which is the earliest commercial variety and more than 2 wk ahead of the other two. Its yield is similar to 'Valenciana Cobra' and higher than the other two varieties. Its storage capacity is similar to 'Grano de Oro' and 'Sintética 14', but greater than 'Valenciana Cobra'.

Key words: *Allium cepa*, cultivar, precocity, storage capacity, single center.

In the irrigated valley of Central South Chile, storage onion varieties (*Allium cepa* L.) usually begin the maturation process in March. This implies that a large proportion of bulbs fail to mature properly, thus affecting their storage capacity resulting in early sprouting and/ or rot. It is known that the presence of a high percentage of immature bulbs or thick-necked onions is related to latitude, planting season, and late storage cultivars (Brewster *et al.*, 1987).

The onion is a cross-pollination plant since it exhibits protandry (Brewster, 2008). Furthermore, it is a biennial plant that produces a bulb in the first year and scapes with its seeds in the second year, allowing the selection of desirable characteristics in the first year. The selected bulbs are planted in the second year after storage to obtain seeds.

According to Havey (2000), due to new technologies available today, many onion breeders have underestimated the power of recurrent phenotypic selection. Moreover, he reports data on the increase of the onion bulb's soluble solid content from 14 to 21% in three generations of mass selection. Mass selection was amply used in Europe to develop open pollination onion varieties up to the 80s

(Brewster, 2008). In Argentina's Instituto Nacional de Tecnología Agropecuaria (INTA) onion breeding program, recurrent selection is used in populations of the Valenciana type, and its objectives are precocity and good storage capacity. Thus, after 12 yr of selection, they have achieved varieties with the desired characteristics, as in the case of 'Cobriza INTA', an onion with excellent storage capacity and darker cataphylls (Galmarini, 2000; Galmarini *et al.*, 2001). There are other reports on the effectiveness of selection on characteristics such as precocity and storage capacity of onions (McCallum *et al.*, 2001; Cardoso and da Costa, 2003). On the other hand, when comparing open-pollinated (OP) onion varieties with hybrid varieties, no consistent superiority of the latter has been found in both yield and bulb quality (Cramer, 2001).

The objective of the Quilmapu Vegetable Breeding Program of the Instituto de Investigaciones Agropecuarias INIA was to select an early storage onion variety that could reach maturity during February in Central South Chile and maintain yield and quality characteristics of the Valenciana type commercial onion cultivars.

MATERIALS AND METHODS

The applied breeding method was recurrent selection with cross-pollination of the plant population, which began with a population of 2000 plants of the Valenciana

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commercial variety with open pollination and established with seedling transplants in October 1994 in the Quilamapu INIA Santa Rosa Experimental Station (36°32' S; 71°55' W) in a volcanic soil classified as Typic Dystrandepts. The climate is typical Mediterranean with a mean annual precipitation of 1200 mm and a mean annual temperature of 13.1 °C, minimum of 3.0 °C in July and maximum of 28.6 °C in January (del Pozo and del Canto, 1999).

Plants were first selected when they reached physiological maturity (tops down before 28 February). After this selection for precocity and subsequent to the curing process, bulbs were selected for size (diameter > 7 cm), shape (spherical), and then stored in warehouses. During storage, all sprouted and soft bulbs were discarded and the rest were planted in the next season for seed production. Since this is a permanent selection process, it is repeated each season. However, when 100% of the plant population reached physiological maturity before 28 February, variety trials started to compare 'Valinia INIA' with other commercial cultivars.

The top third of the bulbs planted for seed production was cut to stimulate sprouting and select those that were single-centered, which is a characteristic required by agribusiness to produce onion rings. Starting in the 2001-2002 season, single-centered bulbs were planted and the percentage of total stored bulbs with this characteristic was registered.

In August of every season, the selected bulbs were planted in rows spaced 80 cm apart and with 30 cm between bulbs. The umbels were cut along with 10 cm of scape during February when they showed ripe seeds due to capsule dehiscence. The umbels were dried after harvest.

From the 2001-2002 to the 2008-2009 season, six variety assays were carried out at the INIA Quilamapu Santa Rosa Experimental Station in the Bío Bío Region and two others at the INIA Raihuén Experimental Station (35°42' S; 71°40' W) in the Maule Region in order to compare 'Valinia INIA' with the 'Sintética 14' (ANASAC), 'Grano de Oro' (Seminis), and 'Valenciana Cobra' (ANASAC) commercial cultivars. Seedlings were established in double rows of plants spaced 10 cm apart on ridges spaced 50 cm apart and reached a population equivalent to 400 000 plants ha⁻¹. Variety assays were planted between 6 and 19 October of each year.

A randomized complete block design was used for these assays along with four replicates and a 2 × 7 m plot.

Evaluations

For each season and location, variety precocity was evaluated by marking the plants that reached physiological maturity before 28 February. Commercial yield was determined at harvest and bulbs with flower stems, those with a diameter less than 5 cm, and thick-necked onions, which were culls. Furthermore, the percentage of

spherical bulbs and those with a diameter greater than 7 cm were determined.

Storage capacity of bulbs harvested in the 2008-2009 season in the Bío Bío Region was evaluated in the last season. In order to evaluate storage capacity, 100 mature and healthy bulbs with a diameter greater than 7 cm were randomly chosen from each replicate in February, placed in mesh bags and taken to a warehouse where the number of sprouted and/or soft bulbs were counted weekly and removed from the mesh bags.

An ANOVA was carried out on the results of all the variety assays with the IRRISTAT (IRRI, 2003) statistical program and means were compared by the LSD test ($P \leq 0.05$).

RESULTS AND DISCUSSION

Selection of 'Valinia INIA'

From the start (February 1995), there were records of the percentage of plants that matured in February; an important gain in this characteristic resulted in yearly increases from 21% in February 1995 to 100% in the last seasons (Table 1).

Although beginning with the February 1995 harvest, spherical bulbs with a diameter greater than 7 cm were selected for storage and seed production in the following season, there are records of the percentage of bulbs with these characteristics only since the 1998-1999 season (Table 1). It can be generally observed that there has been no significant variation of these characteristics over time, except for the 2004-2005 in which bulb size significantly decreased (Table 1). In that season, the yield of all onion varieties was affected (Table 2) due to a severe mildew (*Peronospora destructor*) attack and a high weed population. In a study of genetic variability in onion (Buzar *et al.*, 2007), 58% of the variability was determined by the following descriptors: total sugar content, bulb length, number of days from planting to harvest, percentage of bulbs with an equatorial diameter between 70 and 90 mm, and bulb mean weight.

Table 1. Variation over time of the selected characteristics in 'Valinia INIA' at harvest. All percentages are calculated based on the number of bulbs.

Season	Percentage of tops down in February	Spherical bulbs (% early plants)	Bulbs with diameter > 7 cm (% spherical)	Single-centered bulbs (% stored bulbs)
1994-1995	21	-	-	-
1996-1997	10	-	-	-
1998-1999	81	63	-	-
2001-2002	100	75	91	-
2002-2003	79	68	89	23
2003-2004	83	87	86	90
2004-2005	100	77	31	78
2005-2006	77	63	61	65
2006-2007	80	85	61	78
2007-2008	100	61	76	70
2008-2009	100	80	55	82
2009-2010	100	50	92	82
2010-2011	100	69	72	90

Table 2. Marketable bulb yield of 'Valinia INIA' compared to commercial onion varieties at the INIA Quilamapu (Bío Bío Region) and INIA Raihuén (Maule Region) Experimental Stations.

Season	Valinia INIA	Valenciana Cobra	Grano de Oro	Sintética 14	CV (%)
	t ha ⁻¹				
Quilamapu					
2001-2002	92.6a	81.4ab	91.5a	61.4b	22.2
2002-2003	76.2ab	95.8a	55.0b	71.6ab	21.0
2003-2004	73.4a	63.1a	74.3a	68.6a	15.7
2004-2005	55.4a	51.4a	48.5a	41.8a	21.4
2007-2008	84.1a	83.7a	78.7a	70.1b	6.2
2008-2009	60.5b	69.4a	69.8a	50.0c	8.4
Raihuén					
2007-2008	119.1a	112.4ab	99.8b	77.2c	8.8
2008-2009	124.3a	124.4a	110.8a	73.7b	16.2
Mean	85.7	85.2	78.6	64.3	

Means followed by different letters in the rows are significantly different ($P \leq 0.05$) according to LSD test; CV: coefficient of variation.

With regard to selecting single-centered bulbs (Figure 1), there has also been a gain of up to 90% of the total stored bulbs, but there are variations from year to year (Table 1). Single-centeredness is a low heritability trait, highly influenced by plant vigor, and this characteristic was closely related to bulb size in this study; in general, the biggest bulbs tended to produce multiple centers. It has been observed in onion variety assays conducted in the United States that this characteristic exhibits great variability in each cultivar from season to season (Shock *et al.*, 2005).

Variety assays

It was found in these assays that the yield of 'Valinia INIA' did not differ (healthy bulbs with a diameter > 5 cm) from the commercial varieties and was even higher than 'Sintética 14' (Table 2). Yield, which is a characteristic greatly influenced by crop conditions, depends directly on bulb size and weight. The objectives of these onion breeding programs do not generally include only increasing yield, but rather bulb quality characteristics, precocity, and resistance to disease. In fact, the Valenciana type storage var. Cobriza INTA (INTA Argentina) does not have a higher yield than

the most widely used variety in that country, 'Valcatorce INTA' (Galmarini *et al.*, 2001), which corresponds to the Chilean variety Sintética 14 (González, 1997).

When evaluating precocity, 'Valinia INIA' has a clear advantage with regard to the other commercial varieties with a mean of 1.5 wk ahead of 'Sintética 14', which is the earliest commercial variety and more than 2 wk ahead of the other two varieties ($P \leq 0.05$) (Table 3). The assay was repeated in the 2008-2009 season in both Quilamapu and Raihuén where it was found that the precocity of 'Valinia INIA' is also evident in the Maule Region (Table 4). Another precocity indicator is the absence of thick-necked onions, immature bulbs not in dormancy, which occur when the plant has not reached maturity when the temperature begins to fall and the photoperiod shortens and leads to a reversal of the maturation process of the bulb to vegetative growth (Brewster, 2008). This occurs in Central South Chile when the bulb maturation process is not yet complete in March. It is known that the time required for bulb maturity decreases linearly with increasing temperature and lengthening photoperiod (Khokhar, 2008). 'Valinia INIA' had very few thick-necked onions in the six seasons evaluated in the Bío Bío Region (Table 5). In the assays conducted in Raihuén (Maule Region), none of the varieties produced thick-necked onions in the two seasons.

Table 3. Percentage of 'Valinia INIA' plants that reached physiological maturity in February compared with commercial onion varieties during four seasons in the INIA Quilamapu (Bío Bío Region) Experimental Station.

Season	Valinia INIA	Valenciana Cobra	Grano de Oro	Sintética 14	CV (%)
2001-2002	100a	95b	96b	100a	1.5
2002-2003 ¹	100	50	50	55	
2003-2004	85a	28c	28c	43b	14.6
2004-2005	100a	16b	11b	13b	11.2
Mean	96.3	47.3	46.3	52.8	

Means followed by different letters in the rows are significantly different ($P \leq 0.05$) according to DMS test.

CV: coefficient of variation.

¹No statistical analysis was done because maturity data were not separately reported for each replicate.

Table 4. Precocity of onion varieties determined for the percentage of mature bulbs during January and February 2009 in the INIA Quilamapu (Bío Bío Region) and INIA Raihuén (Maule Region) Experimental Stations.

Date	Valinia INIA	Valenciana Cobra	Grano de Oro	Sintética 14
Quilamapu				
13/01/09	3.9a	0.0b	0.0b	0.0b
16/01/09	5.7a	0.0b	0.0b	0.0b
19/01/09	10.8a	0.0b	0.0b	0.0b
22/01/09	17.9a	0.0b	0.0b	0.8b
26/01/09	66.9a	0.4c	0.0c	17.0b
29/01/09	82.1a	0.8c	0.4c	18.4b
Raihuén				
15/01/09	17.0a	0.0b	0.0b	0.0b
19/01/09	39.1a	0.0b	0.0b	2.7b
23/01/09	91.7a	3.5c	2.4c	30.2b
28/01/09 ¹	-	24.9	18.2	99.7
04/02/09 ¹	-	71.2	67.8	-
07/02/09 ¹	-	99.3	95.3	-

Means followed by different letters in the rows are significantly different ($P \leq 0.05$) according to LSD test.

¹No statistical analysis was done because 'Valinia INIA' had already been harvested.



Figure 1. 'Valinia INIA' single-centered onion bulb.

Table 5. Calculation of percentage of thick-necked onions based on the number of bulbs of the varieties evaluated in the INIA Quilamapu (Bío Bío Region) Experimental Station.

Season	Valinia INIA	Valenciana Cobra	Grano de Oro	Sintética 14	CV (%)
2001-2002	0.0b	4.3a	3.4a	0.0b	9.4
2002-2003	0.0c	12.6b	35.4a	2.8c	16.7
2003-2004	0.0b	12.0a	6.9a	0.0b	14.0
2004-2005	2.2b	22.7a	27.3a	31.5a	14.7
2007-2008	4.7b	13.6a	14.0a	1.7b	12.5
2008-2009	4.7ab	9.2a	9.5a	2.4b	17.3
Mean	1.9	12.4	16.1	6.4	

Means followed by different letters in the rows are significantly different ($P \leq 0.05$) according to LSD test. Data were transformed with square root to decrease the coefficient of variation, but original values are shown. CV: coefficient of variation.

For bulb characteristics such as shape and diameter that were also selected, 'Valinia INIA' did not differ in general from the commercial varieties and had no loss of quality in these aspects (Tables 6 and 7). However, on the average, 'Valinia INIA' has a higher proportion of spherical bulbs (Table 6, Figure 2).

Bulbs from the Maule and Bío Bío Regions stored since the 2008-2009 harvest season were able to express their potential storage capacity in all varieties with sprouted and/or soft bulbs appearing 150 d after being stored. However, the total storage period of bulbs harvested in the Maule Region (Raihuén) was shorter for all varieties. 'Valinia INIA' bulbs harvested in the Bío Bío Region



Figure 2. 'Valinia INIA' spherical yellow onion bulbs.

maintained 50% of bulbs in good conditions up to 320 d of storage, whereas 'Valenciana Cobra' reached only 215 d (Figure 3). This characteristic is important since a variety with a storage potential longer than 6 mo prevents the use of sprouting inhibitors, such as maleic hydrazide (Grevsen and Sorensen, 2004). Furthermore, early storage onion cultivars are affected in their storage capacity

Table 6. Percentage of spherical bulbs in 'Valinia INIA' compared with commercial onion varieties in INIA Quilamapu (Bío Bío Region) and INIA Raihuén (Maule Region) Experimental Stations. Percentages are calculated on the total number of bulbs.

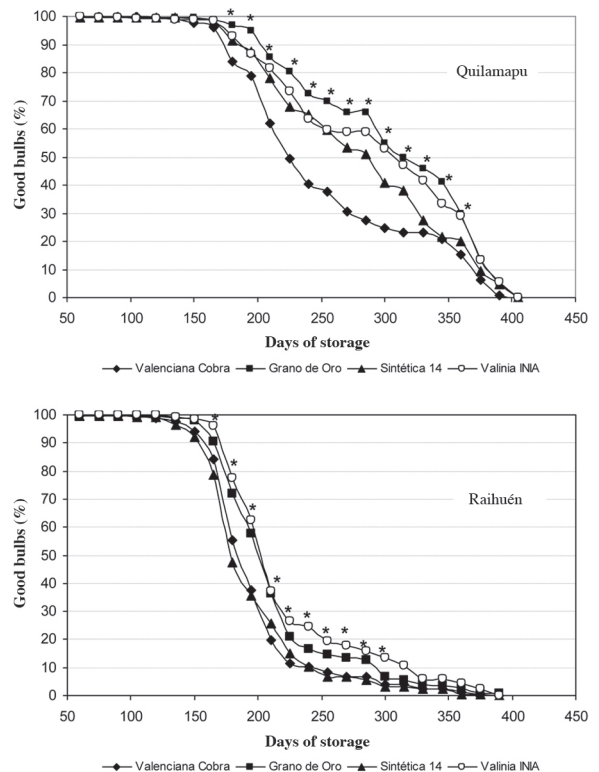
Season	Valinia INIA	Valenciana Cobra	Grano de Oro	Sintética 14	CV (%)
Quilamapu					
2001-2002	75a	62b	72a	72a	7.8
2002-2003	68a	75a	46b	77a	15.8
2003-2004	87a	78a	81a	89a	7.6
2004-2005	77a	47b	53b	45b	12.1
2007-2008	79a	65b	54c	71b	5.6
2008-2009	85a	58b	51c	80a	4.9
Raihuén					
2007-2008	77a	73ab	65b	51c	11.0
2008-2009	79a	72ab	57c	68b	9.0
Mean	78.4	66.3	59.8	69.1	

Means followed by different letters in the rows are significantly different ($P \leq 0.05$) according to LSD test. CV: coefficient of variation.

Table 7. Percentage of bulbs with diameter > 7 cm in 'Valinia INIA' compared with commercial onion varieties in the INIA Quilamapu (Bío Bío Region) and INIA Raihuén (Maule Region) Experimental Stations. Percentages are calculated on the number of commercial bulbs.

Season	Valinia INIA	Valenciana Cobra	Grano de Oro	Sintética 14	CV (%)
Quilamapu					
2001-2002	91a	95a	91a	67b	16.4
2002-2003	89a	98a	90a	90a	6.7
2003-2004	86a	83a	85a	68b	7.3
2004-2005	31a	41a	34a	29a	37.1
2007-2008	85a	89a	84a	69b	7.2
2008-2009	57b	78a	72ab	27c	16.0
Raihuén					
2007-2008	95a	96a	98a	89b	2.2
2008-2009	97a	95a	92a	70b	11.4
Mean	78.9	84.4	80.8	63.6	

Means followed by different letters in the rows are significantly different ($P \leq 0.05$) according to LSD test. CV: coefficient of variation.



Asterisks indicate significant differences in the measurements among varieties according to the LSD test ($P \leq 0.05$).

Figure 3. Evaluation of bulb storage capacity of onion varieties harvested in February 2009 in INIA Quilamapu (Bío Bío Region) and INIA Raihuén (Maule Region) expressed as a percentage of good bulbs (unsprouted and not soft) over time.

compared with later cultivars (Muro *et al.*, 2006), but this is not observed in 'Valinia INIA'.

CONCLUSIONS

The Quilmapu Vegetable Breeding Program of INIA obtained and registered (Lista de variedades protegidas, Servicio Agrícola y Ganadero de Chile, Resolución 37/11) 'Valinia INIA' as a Valenciana type storage onion variety: early maturing, medium-sized bulb, spherical, yellow, high percentage of single-centered bulbs, and resistant to sprouting in storage.

Valinia INIA, una nueva variedad de cebolla de guarda precoz para la zona centro sur de Chile.

En la zona centro sur de Chile es habitual que las variedades de cebolla (*Allium cepa* L.) de guarda que se comercializan en el país inicien el proceso de maduración preferentemente en marzo, lo que conlleva a que una gran proporción de bulbos no madure adecuadamente, no resistiendo el almacenaje por un tiempo prolongado. Esta situación llevó al programa de hortalizas del Instituto de Investigaciones Agropecuarias INIA Quilmapu a la selección de una variedad de cebolla de madurez precoz. El método de mejoramiento fue selección recurrente con cruzamiento libre de las plantas, la que se inició el año 1994 sobre una población de 2000 plantas de la variedad comercial Valenciana. Las plantas se seleccionaron, en primera instancia, cuando alcanzaban la madurez fisiológica (doblamiento del cuello de la planta antes del 28 de febrero), y posteriormente por su forma, tamaño, capacidad de guarda y bulbos con centro único. Como resultado del programa se obtuvo 'Valinia INIA', una variedad de cebolla de guarda tipo Valenciana, de maduración temprana, bulbo de tamaño medio, esférico, color dorado y resistente a la brotación en almacenaje. Desde la temporada 2001-2002 hasta la temporada 2008-2009 se hicieron ensayos varietales para comparar 'Valinia INIA' con los cultivares comerciales 'Sintética 14', 'Grano de Oro' y 'Valenciana Cobra'. En todas las temporadas, 'Valinia INIA' superó en precocidad a las demás variedades, adelantándose en promedio 1,5 semanas a 'Sintética 14', que es la variedad comercial más precoz, y más de 2 semanas a las otras dos. En rendimiento fue similar a 'Valenciana Cobra' y superior a las otras dos. Su capacidad de guarda fue similar a 'Grano de Oro' y 'Sintética 14', pero superior a 'Valenciana Cobra'.

Palabras clave: *Allium cepa*, cultivar, precocidad, capacidad de guarda, centro único.

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